

A Tropical Seasonal Rain Forest at its Altitudinal and Latitudinal Limits in Southern Yunnan, SW China

H. ZHU

Xishuangbanna Tropical Botanical Garden,
The Chinese Academy of Sciences,
Xue Fu Road 88,
Kunming 650223, Yunnan, P. R. China

Abstract

The tropical seasonal rain forest (semi-evergreen rain forest) in Caiyanghe Nature Reserve, Simao, Yunnan, China, is at the northern and altitudinal limits of tropical rain forest in Asia. It shares the main physiognomic characteristics of tropical rain forest. Compared with lowland rain forests in China and equatorial regions in Asia, it has lower species diversity with more micro- and nano-phanerophytes and herbaceous phanerophytes in the life form spectra, more microphyllous plants and more plants with non-entire leaves. In floristic composition, it is dominated by tropical Asian elements and characterized by the Indo-Malayan tropical flora. It is suggested that the occurrence of tropical rain forest in southern Yunnan is more influenced by topography and local habitats than the regional climate.

Introduction

Tropical rain forests occur mainly in those wet tropical areas between the Tropics of Cancer and Capricorn with a mean annual temperature above 24°C and the mean monthly temperature above 18°C in the coldest month; and an annual rainfall of at least 1700 mm and usually above 2000 mm (Richards 1996). However, the northern and southern borders of tropical rain forests do not coincide exactly with any latitudinal limits and in some places they extend somewhat beyond the Tropics of Cancer and Capricorn. For example, the Indo-Malayan rain forests extend beyond the Tropic of Cancer at 27° 31' N in northeastern India (Proctor *et al.*, 1998), Myanmar (Kingdon-Ward 1945) and southern Yunnan, China (Zhu 1997), where they occur as small patches forming mosaics within the monsoon forests (Whitmore 1990; Richards 1996; Morley 2000). These Indo-Malayan tropical rain forests north of the Tropic of Cancer are little known apart from some descriptive accounts (Kingdon-Ward 1945; Proctor *et al.* 1998).

Southernmost Yunnan, i.e. Xishuangbanna, which borders Myanmar and Laos, is a mountainous area on the northern margin of tropical Southeast Asia. Tropical rain forest in this region was first mentioned by Wang (1939). Between 1955 and 1960, these forests in southern Yunnan were investigated in detail by

Sino-Russian expeditions and Yunnan University. It was then suggested that biogeographically tropical rain forests existed in southern Yunnan, but these were considered to be a type different from the ones in Indo-Malaysia because of the lack of representatives of Dipterocarpaceae, which dominates the rain forests of tropical SE Asia (Fedorov 1958; Qu 1960; Wang 1961). Since the tropical rain forest in Xishuangbanna occurs at the climatic limits of rain forest (lower mean annual temperature and annual precipitation than usual) and has a clear change of physiognomy between different seasons, Chinese botanists prefer the term 'tropical seasonal rain forest' (Wu 1987; Zhu 1992; Cao 1996; Jin 1997), although it conforms to the semi-evergreen rain forests of SE Asia as defined by Whitmore (1984, 1990) and to a lowland rain forest (Zhu 1997).

Although several studies on the tropical rain forests in southern Yunnan have been carried out (Wu 1987; Xu *et al.* 1987; Jin 1997; Zhu *et al.* 1998a, 2002), little has been published in English (Cao & Zhang 1997; Zhu 1997; Zhu *et al.* 1998b) and most of these focused on the tropical seasonal rain forest in Xishuangbanna where they occur only in areas below 900 m asl.

Recently, tropical seasonal rain forest was found in the Caiyanghe Nature Reserve, Simao County, just north of Xishuangbanna at an altitude of 1300 m and for which Zhu *et al.* (2000) provided a descriptive report. However, the occurrence of tropical seasonal rain forest here is unusual more for its high altitude than its northerly latitude. Its floristic composition and physiognomy are presented in this paper.

The Caiyanghe Nature Reserve

Location and topography

The Nature Reserve is in southeast Simao County, Yunnan, 101°7'~101°15' E 22°30'~22°38' N (Fig. 1). It has a mountainous topography with its main range running east to west with the highest elevation (1698 m) in the north and the lowest elevation (980 m) on the Caiyanghe River on the southwest slope of the mountain.

Climate and Soil

There are no meteorological records for Caiyanghe, but from the records from Simao county climate station c. 20 km away, the region has a monsoon climate with a mean annual temperature of 17.7°C, a mean for the coldest month of 11.4°C, annual temperature accumulation (the sum of daily temperature means of > 10°C) of 6253°C and mean annual precipitation of 1547.6 mm, of which more than 80% falls during the rainy season between May and the end of October.

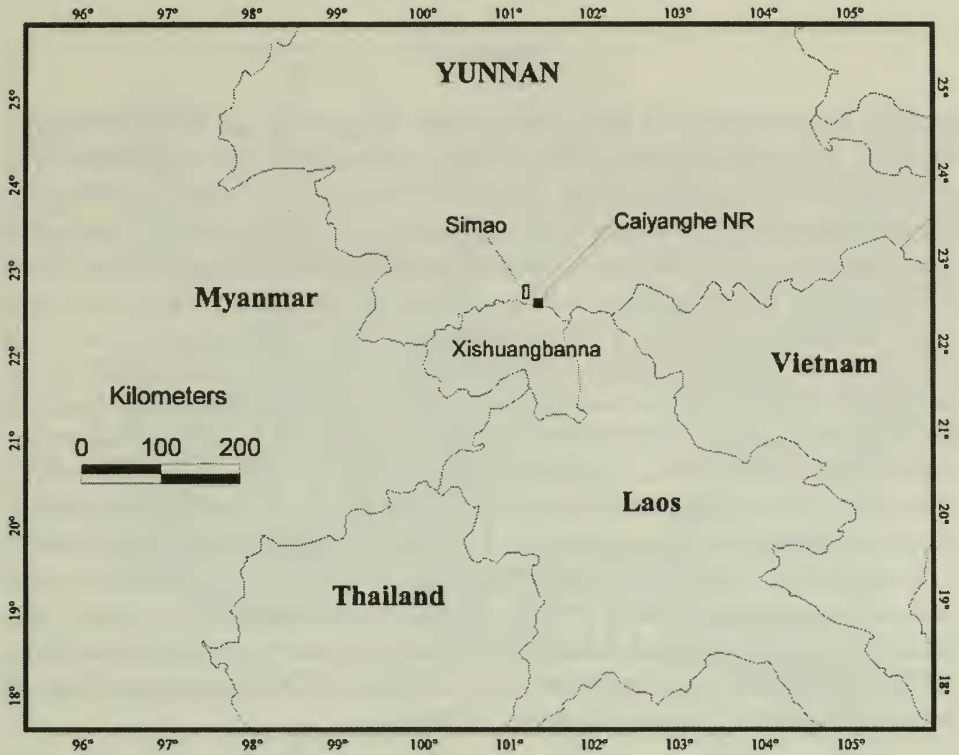


Figure 1. The location of Caiyanghe Nature Reserve in Simao, southern Yunnan, Southwestern China

The soil is oxisol with a deep solum but a thin humus horizon. The oxisol was derived from sandstone (above 1200 m asl) and from muddy shale (below 1300 m asl).

Vegetation types

The main vegetation formation at Caiyanghe is a montane evergreen broad-leaved forest in terms of physiognomy and habitat, which was called monsoon evergreen broad-leaved forest in Chinese literature (Wu 1987). It occurs on mountain slopes and summits above 1200 m asl and in valleys at 1300~1500 m altitude, and makes up 92% of the natural forest cover in the Nature Reserve (Cao, 2003).

The focus of this study was on the tropical seasonal rain forest in Caiyanghe, which makes up less than 2% of the natural forest cover in the Nature Reserve and which is dominated by *Pometia tomentosa* (Sapindaceae) and *Garuga floribunda* var. *gamblei* (Burseraceae). It occurs only in valleys below 1300 m altitude and usually on south-facing slopes. The tropical seasonal rain forest in Caiyanghe is an extension of the ones in Xishuangbanna.

Methods

Several small patches of tropical seasonal rain forest occur in the Nature Reserve. A representative stand in a valley was selected for a plot study. The plot size was 25 m x 100 m (with the plot length along the valley). All trees in the plot were identified and their dbh (minimum 5 cm), height and crown cover were measured. The plot was divided into five subplots (25 m x 20 m each) so that frequency of tree species could be calculated. The forest profile was drawn from a strip stand of 50 m x 10 m in the plot. Five small plots of 5 m x 5 m each were set up for a floristic survey of the understorey. In these small plots, saplings, shrubs and herbaceous plants were counted. Epiphytes and lianas in the plot were identified and their abundance estimated visually. Importance value indices (IVI) for tree species were calculated (Curtis & McIntosh 1951). A rank/abundance diagram (Magurran 1988) of species in the plot was plotted. Shannon-Wiener's indexes for species diversity (Shannon and Wiener 1949) were calculated from the plot data. Physiognomy (life forms and leaf size) was analyzed using Raunkiaer's criteria (1934). Specimens were collected and identified. Species authorities follow Flora Reipublicae Popularis Sinicae (Flora of China). Specimens are deposited in the herbarium of Xishuangbanna Tropical Botanical Garden, Chinese Academy of Science.

Results

Species composition

The tropical seasonal rain forest in the Nature Reserve can be recognized as a *Garuga floribunda* var. *gamblei*-*Pometia tomentosa* formation based on the dominant species. It occurs in the valleys below 1300 m altitude. It is c. 35 m tall with three tree layers (Fig. 2). The top tree layer, composed of emergent trees with buttresses, is 25~35 m tall and has a crown cover of 40~50%. The most dominant tree species in this layer is *Pometia tomentosa*. The second tree layer is 10~25 m tall with a crown cover of 50-60%. The most dominant tree is *Alphonsea monogyna* (Annonaceae). The third tree layer is 3~10 m tall with a crown cover of 50% and *Cleidion spiciflorum* (Euphorbiaceae) is the most dominant species. Some species in the tree layer are cauliflorous and many have leaves with a drip tip. The sapling-shrub layer is 1~3 m tall with a cover of 30~40 %. It is composed mainly of juvenile trees. The commonest shrub species is *Mycetia glandulosa* (Rubiaceae). The herb layer is 1 m tall with a cover of c. 25%. The woody lianas are abundant, but there are relatively few epiphytes.

Evergreen trees both in species and individuals dominate the forest. Only two deciduous species were recorded from the forest plot. *Garuga floribunda*



Figure 2. Profile diagram of the tropical seasonal rain forest in Caiyanghe
 1 *Pometia tomentosa*, 2 *Cleidion spiciflorum*, 3 *Alphonsea monogyna*,
 4 *Cinnamomun bejolghota*, 5 *Phoebe lanceolata*, 6 *Elaeocarpus sikkimensis*,
 7 Dead tree, 8 *Garuga floribunda* var. *gamblei*, 9 *Saurauia macrotricha*,
 10 *Baccaurea ramiiflora*, 11 *Macropanax dispermus*, 12 *Flacourtia rukam*,
 13 *Duabanga grandiflora*, 14 *Phoebe puwenensis*

var. *gamblei*, although not dominant in individuals, is the largest deciduous tree in canopy layer, and *Radermachera igneum* (Bignoniaceae) in the second tree layer.

The species composition and their phytosociological importance are given in the Appendix.

Physiognomy

The forest in Caiyanghe is characterized by phanerophytes, of which woody phanerophytes contribute the most (Table 1). Among 52 woody plant species from the plot, ones with mesophyllous leaves contribute 69.2% of the total, ones with microphyllous leaves 17.3% and ones with macrophyllous leaves 13.5%.

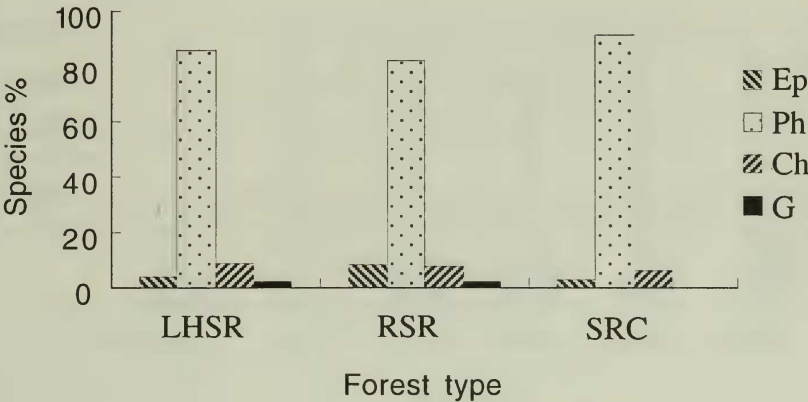
Compared with tropical seasonal rain forests at lower elevations in Mengla and Mengyang of Xishuangbanna (Zhu *et al.* 1998b), the forest in

Table 1. Life form spectrum of the plants from the tropical season rain forest in Caiyanghe.

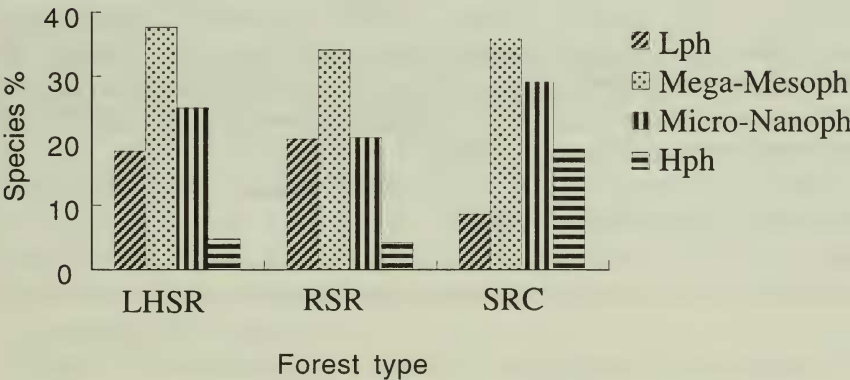
Life form	Epiphyte	Liana	Woody plants				Herb plants		Total
			Megaph.	Mesoph.	Microph.	Nanoph.	Hph.	Ch	
No. of species	2	7	9	20	18	5	15	5	81
%	2.5	8.6	11.1	24.7	22.2	6.2	18.5	6.2	100

Megaph.: Megaphanerophytes; Mesoph.: Mesophanerophytes; Microph.: Microphanerophytes; Nanoph.: Nanophanerophytes; Hph.: Herbaceous phanerophytes; Ch: Chamaephytes

Caiyanghe has fewer liana species, but more micro- and nano-phanerophytes, and herbaceous phanerophytes (Fig. 3), Caiyanghe rain forest has a similar leaf size spectrum to seasonal rain forests in Xishuangbanna and lowland evergreen rain forest in northeastern India, which show a higher percentage of microphyllous plants than those of equatorial lowland rain forests in Borneo and the Philippines (Fig. 4). Like the lowland evergreen rain forest in northeastern India, the rain forest in Caiyanghe also has a higher percentage of species with simple leaves and non-entire leaves (Table 2). A relatively high proportion of plants with non-entire leaf margins could be a character of the rain forest either at latitudinal or altitudinal limits because a higher proportion of non-entire leaved species is usually present in subtropical evergreen broad-leaved forest in eastern Asia and in tropical montane forest in southeastern Asia.



a. For all plant species



b. For phanerophytes

Figure 3. Comparison of life form spectra from the tropical seasonal rain forest in Caiyanghe and the tropical seasonal rain forests at lower altitude in southern Yunnan In Caiyanghe - SRC: Seasonal rain forest. In southern Yunnan (Zhu *et al.*, 1998b) - LHSR: Lower hill seasonal rain forest; RSR: Ravine seasonal rain forest. Ep=Epiphyte; Ph=Phanerophyte; Ch=Chamaephytes; G=Geophyte; Lph=Liana-phanerophyte Hph=Herbaceous phanerophyte; Mega-Mesoph=Megaphanerophyte + Mesophanerophyte; Micro-Nanoph=Microphanerophyte + Nanophanerophyte

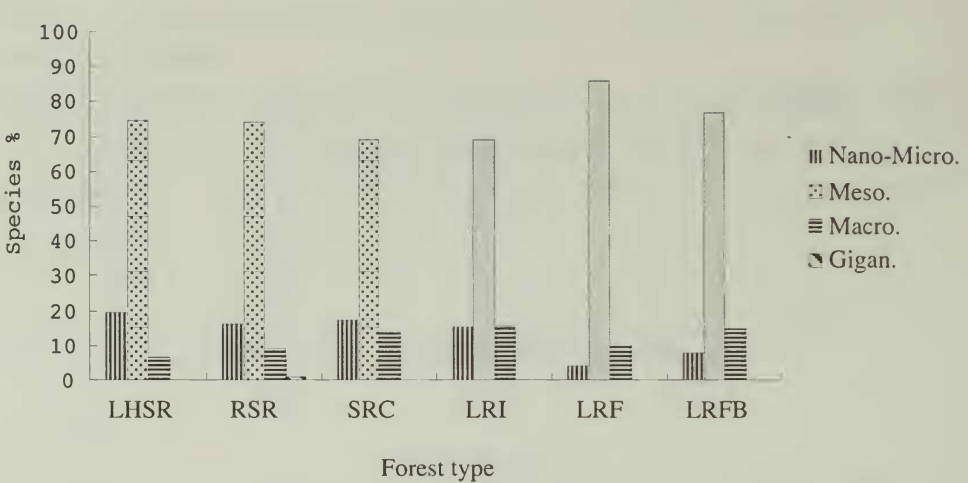


Figure 4. Comparison of leaf size spectra from tropical rain forests in Caiyanghe, southern Yunnan, India and equatorial lowlands
Caiyanghe - SRC; *Southern Yunnan* - LHSR: Lower hill seasonal rain forest (Zhu , 2000); RSR: Ravine seasonal rain forest (Zhu et al., 1998b); *India* - LRI: Lowland evergreen rain forest (Proctor et al., 1998); *Equatorial lowlands* - LRF: Lowland rain forest in the Philippines (Brown,1919); LRFB: Lowland rain forest in Borneo (Vareschi, 1980).
Nano-Micro.: Nanophyll + Microphyll; Meso.: Mesophyll; Macro.: Macrophyll; Gigan.: Gigantophyll

Table 2. Comparison of leaf type and leaf margin spectra for phanerophytes from the tropical rain forest in Caiyanghe, the rain forest in southern Yunnan, the rain forest in northeastern India and the equatorial tropical rain forest in New Guinea.

Forest type	Leaf type		Leaf margin	
	Simple	Compound	Entire	Non-entire
Tropical seasonal rain forest in Caiyanghe	78.9	21.1	76.9	23.1
Tropical seasonal rain forest in Xishuangbanna, southern Yunnan ³	78.6	21.4	80	20
Lowland evergreen rain forest in northeastern India ¹	80.5	19.5	72.9	27.1
Tropical rain forest in New Guinea ²	77	23	85	15

¹Proctor et al. (1998); ²Pajmans (1970); ³Zhu (1997).

Table 3. Comparison of species diversity among different tropical rain forest in southern Yunnan.

Forest type	Plot code	Area (m ²)	Alt (m)	Slope (°)	N.S.	N.I.	H'
Tropical seasonal rain forest in Caiyanghe	CYH	2500	1200	25	29	154	2.528
Ravine seasonal rain forest ¹ in Menglun, Xishuangbanna	940102	2500	650	5-10	49	108	3.586
	940103	2500	675	30	57	194	3.573
	940101	2500	700	25	48	96	3.599
Lower hill seasonal rain forest ¹ in Menglun, Xishuangbanna	931206	2500	650	10	52	182	3.377
	9201	2500	680	30	46	207	3.159
Seasonal rain forest dominated by dipterocarp ² in Mengla, Xishuangbanna	Dipt-I	2500	700	20	57	284	3.356
	Dipt-II	2500	800	30	56	186	3.116

H': Shannon-Wiener's diversity indexes; Base:2.718283; N.S.: Number of species; N.I.: Number of individuals.
¹data from Zhu *et al.* (1998b) ²data from Zhu (2000)

Tree population patterns and diversity

A comparison of the rank/abundance diagram of species based on 0.25 ha plot each between the tropical rain forest in Caiyanghe and other tropical rain forest types in southern Yunnan was made to show tree population patterns (Fig. 5). The graph for the rain forest in Caiyanghe has a shorter tail in the species sequence curve, which indicates fewer species with only one or two individuals than for the other rain forests.

A total of 29 tree species > 5 cm d.b.h. was obtained from a plot of 0.25 ha in tropical seasonal rain forest at Caiyanghe. Comparable sites in seasonal rain forests in valleys and on lower hills, and the seasonal rain forest dominated by dipterocarps at lower altitudes in Xishuangbanna yielded 51, 49 and 56 tree species respectively (Table 3). The Shannon-Wiener's diversity index is lower for the forest in Caiyanghe. This indicates that the tropical rain forest in Caiyanghe at both of the altitudinal and latitudinal limits has lower species diversity than the other rain forests at the latitudinal limit in southern Yunnan.

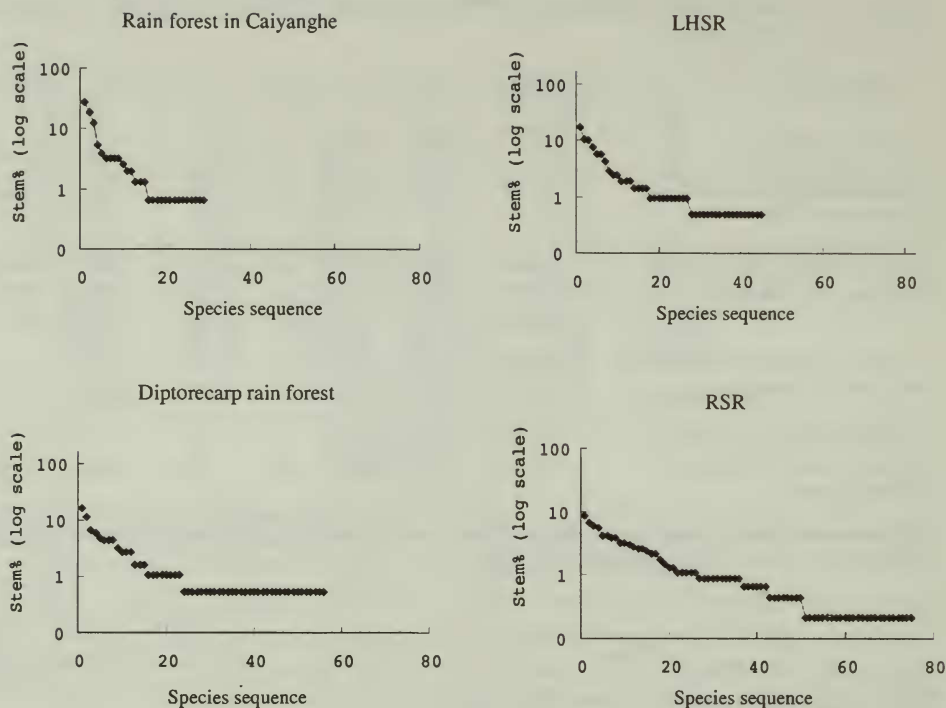


Figure 5. Comparison of rank/abundance diagram of tree species between the tropical seasonal rain forest in Caiyanghe and other tropical rain forest types in southern Yunnan

LHSR*: Lower hill seasonal rain forest; RSR*: Ravine seasonal rain forest; Dipterocarp rain forest*: Seasonal rain forest dominated by dipterocarps.

* Zhu (2000).

Discussion

The tropical rain forest in southern Yunnan is considered to be a type of Indo-Malayan rain forest at the northern margin of tropical Asia as judged by its similarity to the Indo-Malayan forests in forest profile, physiognomy and floristic composition (Zhu 1997). Occurring at the area with a seasonal dry period, the tropical rain forest in southern Yunnan is a semi-evergreen rain forest with deciduous trees making up 5 – 30% of the number of canopy species or individuals (Zhu *et al.* 1998a). Interestingly, tropical seasonal rain forests in Yunnan have a profile similar to those of lowland rain forests although it occurs in mountain habitats with higher altitude (Zhu, 1997). In terms of physiognomy, the tropical rain forest in Yunnan is similar to the lowland semi-

Table 4. Temperature and rainfall distribution recorded at different sites in southern Yunnan.

Locality	Lat.	Alt. (m)	AT	≥10°C TC	MTH	MTC	AR (mm)	RD (Nov.—Apr.) (May—Oct.)	RR	RD/RR	RH
Mengla, Xishuangbanna	N21°49	634	21.0	7639	24.6	15.2	1531.9	281.6	1250.3	0.23	86%
Mengyang, Xishuangbanna	N22°06	740	20.8	7592	24.6	14.7	1193.7	176.0	1017.9	0.15	80%
Simao	N22°47	1302	17.7	6253	21.7	11.6	1547.6	202.9	1311.3	0.15	82%

AT: annual mean temperature; ≥10°C TC: Annual temperature accumulation; MTH: monthly mean temperature of the hottest month; MTC: monthly mean temperature of the coldest month;
AR: Annual rainfall; RD: Rainfall during dry season; RR: Rainfall during rainy season; RH: Relative humidity. (Data for Simao from Cao, 2003; data for Mengla and Mengyang from Xu *et al.*, 1987

evergreen rain forests in SE Asia as defined by Whitmore (1984, 1990). The rain forest in Caiyanghe, although occurring further north and at higher elevations with annual mean temperatures and annual temperature accumulation lower than those Xishuangbanna of southern Yunnan (Table 4) is up to 35 – 40 m tall with three tree layers. It has the main physiognomic characteristics of tropical rain forest, such as the upper layer trees with huge buttresses, the lower layer trees with cauliflory, leaves with drip tips, and the relative abundance of woody lianas and some epiphytes. Like the seasonal rain forest in Xishuangbanna, the rain forest in Caiyanghe is also semi-evergreen due to some deciduous trees in the canopy layer. The rain forest in Caiyanghe is the extension of seasonal rain forest in Xishuangbanna. It is not only one of the northern-most types of the Indo-Malayan rain forests, but it is also the northern-most and the highest altitudinal type of tropical seasonal rain forest in Yunnan. Beyond the northern watershed line of the mountain of Caiyanghe, tropical rain forest is not seen, although there are still some tropical floristic elements. It is possible that the tropical rain forest in southern Yunnan never extended beyond the mountains of Caiyanghe in the north.

The tropical seasonal forest at Caiyanghe has also lower species diversity than the seasonal rain forests at lower altitude in Xishuangbanna of southern Yunnan. However, the differences in physiognomy and species diversity observed from the seasonal rain forest in Caiyanghe do not surpass the differences observed in other locations in the climatic and geographic zone categorized as tropical.

In floristic composition, the seasonal rain forest in Caiyanghe is dominated by tropical Asian elements that characterize the Indo-Malayan flora, as do the other tropical rain forests in southern Yunnan. However, the dominant tree species, such as *Pometia tomentosa*, *Alphonsea monogyna*, *Duabanga grandiflora* (Sonneratiaceae), *Garuga floribunda* var. *gamblei* and *Terminalia myriocarpa* (Combretaceae), are all near the northern limits of their tropical Asian distributions. Some strictly tropical Asian species, such as *Barringtonia macrostachya* (Lecythidaceae), *Myristica yunnanensis* and *Knema furfuracea* (Myristicaceae), and *Pouteria grandiflora* (Sapotaceae), which are the climax species in the tropical seasonal rain forest in the lowlands of southern Yunnan, are not seen in the rain forest in Caiyanghe. This shows that the tropical seasonal rain forest in Caiyanghe is really at the altitudinal and latitudinal limits in southern Yunnan.

Compared with equatorial lowland rain forest in southeast Asia, the seasonal rain forest in Caiyanghe has more microphyllous plants and more plants with non-entire leaves, which may be a result of the fact that it occurs at both latitudinal and altitudinal limits and shows some similarities with subtropical evergreen broad-leaved forest in eastern Asia and montane rain forests in southeastern Asia.

Although the tropical rain forest in Caiyanghe is composed mainly of tropical floristic elements, the ones of strictly tropical distribution are still under-represented compared with the Malesian flora. Many Malesian elements reach to their northern limits here. This indicates that the tropical rain forest is floristically transitional to the subtropical forests of SW China.

According to the climatic classification for tropical rain forest regions (Richards 1996), the Caiyanghe Nature Reserve falls outside it because it has a mean annual temperature of just 17.7°C and a coldest monthly mean of 11.4°C. The tropical seasonal rain forest in Caiyanghe therefore occurs at the climatic limits of tropical rain forest. Its occurrence is unusual more for its high altitude than its northerly latitude.

The tropical seasonal rain forest in Caiyanghe occurs quite locally in limited habitats in valleys. Its occurrence therefore seems to correspond more with topography than with regional climate. The tropical seasonal rain forest, which occurs locally in wet valleys and on lower slopes, forms a mosaic with montane evergreen broad-leaved forests and monsoon forests in southern Yunnan. This implies that the distribution of tropical rain forest in southern Yunnan is more influenced by local habitats and microclimates than regional climate.

Acknowledgements

This project was funded by The National Natural Science Foundation of China (40271048) and the Yunnan Natural Science Foundation (2002C0067M). Mr. Li Bao-gui is thanked for help with fieldwork and Mr. Shi Ji-pu and Ms. Cai Lin for help with the plot data analysis. I also thank Dr. Ruth Kiew and the anonymous reviewers for their constructive comments on this article.

References

- Brown, W.H. 1919. *Vegetation of the Philippine Mountains*. Bureau of Sciences (Publ. 13), Manila, the Philippines.
- Cao M. 1996. Tree species composition of a seasonal rain forest in Xishuangbanna, Southwest China. *Tropical Ecology*. 37: 18–192.
- Cao M. and Zhang J.H. 1997. Tree species diversity of tropical forest vegetation in Xishuangbanna, SW China. *Biodiversity and Conservation*. 6: 995–1006.
- Cao S.S. (ed.) 2003. *Caiyanghe Nature Reserve*. Yunnan Sci. & Tech. Press, Kunming, China. p. 17.

- Curtis, J.T. and R.P. MacIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*. **32**: 467–496.
- Fedorov, A. A. 1958. The tropical rain forest of China (in Russia with English summary). *Botanicheskii Zhurnal S.S.S.R.* **43**: 1385–1480.
- Jin Z.Z. 1997. The diversity features of the floristic elements in the tropical rain forest of Xishuangbanna, Yunnan. *Acta Botanica Yunnanica*. Suppl. **9**: 129–148.
- Kingdon-Ward, F. 1945. A sketch of the botany and geography of north Burma. *Journal of Bombay Natural History Society*. **45**: 16–30.
- Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Croon Helm Limited, London, UK.
- Morley, J.R. 2000. *Origin and Evolution of the Tropical Rain Forests*. John Wiley. England:, pp. 1–7.
- Paijmans, K. 1970. An analysis of four tropical rain forest sites in New Guinea. *Journal of Ecology*. **58**: 77–101.
- Proctor, J., K. Haridasan, and G.W Smith. 1998. How far north does lowland evergreen tropical rain forest go? *Global Ecology and Biogeography Letters*. **7**: 141–146.
- Qu, Z.X. 1960. Nature reserves in Yunnan. (in Chinese). *Journal Yunnan University (Natural Science)*. **1**: 1–4.
- Raunkiaer, C. 1934. *The Life Forms of Plants and Statistical Plant Geography*. Oxford University Press, Oxford, UK.
- Richards, P.W. 1996. *The Tropical Rain Forest: an Ecological Study*. Second edition, Cambridge Univ. Press, Cambridge, UK. pp.1–19, 159–205.
- Shannon, C.E. and W. Wiener. 1949. *The Mathematical Theory of Communication*. Univ. Illinois Press, Urbana, USA.
- Vareschi, V. 1980. *Vegetationsoekologie der Tropen*. Stuttgart, Eugen. Ulmer, Germany. pp. 141–148.
- Wang C.W. 1939. *A Preliminary Study of the Vegetation of Yunnan*. Bull. Fan. Mem. Inst. Bot. IX
- Wang C.W. 1961. The forests of China with a survey of grassland and desert vegetation. *Maria Moors Cabot Foundation Publication No. 5*. Harvard Univ. Cambridge Massachusetts., pp. 155–164
- Whitmore, T.C. 1984. *Tropical Rain Forests of Far East*. (Second edition). Clarendon Press, Oxford, UK.

- Whitmore, T.C. 1990. *An Introduction to Tropical Rain Forests*. Clarendon Press, Oxford, U.K. pp. 9–36.
- Wu C.Y. 1987. *Vegetation of Yunnan*. Science Press, Beijing, pp. 97–143.
- Xu Y.C., Jiang H.Q. and Quan F. 1987. *Reports on the Nature Reserve of Xishuangbanna*. Yunnan Sci. & Techn. Press, Kunming. (in Chinese)
- Zhu H. 1992. The tropical rainforest vegetation in Xishuangbanna. *Chinese Geographical Science*. 2 (1): 64–73
- Zhu H. 1997. Ecological and biogeographical studies on the tropical rain forest of south Yunnan, SW China with a special reference to its relation with rain forests of tropical Asia. *Journal of Biogeography*. 24: 647–662.
- Zhu H., Wang H. and Li B.G. 1998a. Research on the tropical seasonal rainforest of Xishuangbanna, South Yunnan. *Guihaia*. 18 (4): 371–384 (in Chinese with English abstract).
- Zhu H., Wang H. and Li B.G. 1998b. The structure, species composition and diversity of the limestone vegetation in Xishuangbanna, SW China. *Gardens' Bulletin Singapore*. 50: 5–33.
- Zhu H., Li B.G., Deng S.C., Cao Y.G. and Zhang X.B. 2000. Tropical rain forest of Caiyanghe Nature Reserve, Simao, Yunnan and its biogeographical significance. *Journal of Forestry University NE China*. 28 (5): 87–93 (in Chinese with English abstract).
- Zhu H. 2000. *Ecology and Biogeography of the Tropical Dipterocarp Rain Forest in Xishuangbanna*. Yunnan Science & Technology Press, Kunming.
- Zhu H. and Zhou H.X. 2002. A comparative study on the tropical rain forests in Xishuangbanna and Hainan. *Acta Botanica Yunnanica*. 24: 1–13.

Appendix. Plot table of the tropical rain forest in Caiyanghe Nature Reserve, Simao, Yunnan

Plot information:

Plot size: 25 x 100 m	Altitude: 1200 m	Slope aspect: SW
Height of forest: 40 m	Coverage: >95%	Slope: 25°

Trees

Name of trees	Stem%	Base area%	Frequency%	IVI ¹
<i>Pometia tomentosa</i>	12.34	28.10	8.47	48.91
<i>Alphonsea monogyna</i>	27.27	5.52	8.47	41.27
<i>Duabanga grandiflora</i>	5.19	22.47	3.39	31.05
<i>Cleidion spiciflorum</i>	18.83	2.05	8.47	29.36
* <i>Garuga floribunda</i> var. <i>gamblei</i>	3.25	13.52	6.78	23.55
<i>Terminalia myriocarpa</i>	0.65	14.82	1.69	17.16
<i>Homalium laoticum</i>	3.90	6.34	6.78	17.02
<i>Garcinia cowa</i>	3.25	1.09	5.08	9.42
<i>Ostodes paniculata</i>	3.25	0.43	5.08	8.76
<i>Phoebe puwenensis</i>	3.25	0.38	5.08	8.72
<i>Cinnamomum bejolgota</i>	2.60	1.05	3.39	7.04
<i>Baccaurea ramiflora</i>	1.95	0.24	3.39	5.58
<i>Syzygium szemaoense</i>	1.30	0.48	3.39	5.16
<i>Mitrephora maingayi</i>	1.30	0.38	3.39	5.07
<i>Randia wallichii</i>	1.30	0.08	3.39	4.76
<i>Flacourtia rukam</i>	1.95	0.97	1.69	4.61
<i>Elaeocarpus sikkimensis</i>	0.65	0.82	1.69	3.16
<i>Amoora tetrapetala</i>	0.65	0.53	1.69	2.87
<i>Horsfieldia kingii</i>	0.65	0.21	1.69	2.55
* <i>Radermachera igneum</i>	0.65	0.17	1.69	2.51
<i>Caryota monostachys</i>	0.65	0.12	1.69	2.46
<i>Phoebe lanceolata</i>	0.65	0.12	1.69	2.46
<i>Drypetes indica</i>	0.65	0.03	1.69	2.38
<i>Saurauia macrotricha</i>	0.65	0.03	1.69	2.37
<i>Dichapetalum gelonioides</i>	0.65	0.02	1.69	2.36
<i>Syzygium cathayensis</i>	0.65	0.02	1.69	2.36
<i>Magnolia henryi</i>	0.65	0.01	1.69	2.36
<i>Trigonostemon thyrsoideum</i>	0.65	0.01	1.69	2.36
<i>Glycosmis pentaphylla</i>	0.65	0.01	1.69	2.36
Total: 29 species	100	100	100	300

¹Importance Value Indices; *Deciduous trees

Sapling and shrub (from 5 subplots of 5 x 5 m)

Species	Individual	Frequency %	Life form
<i>Mycetia glandulosa</i>	10	60	shrub
<i>Cleidion spiciflorum</i>	7	40	sapling
<i>Alphonsea monogyna</i>	4	40	sapling
<i>Trigonostemon thyrsoides</i>	3	40	sapling
<i>Garuga floribunda</i> var. <i>gamblei</i>	3	20	sapling
<i>Pandanus furcatus</i>	3	40	shrub
<i>Magnolia henryi</i>	2	40	sapling
<i>Desmos dumosus</i>	2	20	shrub
<i>Baccaurea ramiflora</i>	2	40	sapling
<i>Leea compactiflora</i>	2	40	shrub
<i>Mitrephora maingayi</i>	2	20	sapling
<i>Litsea monopetala</i>	2	40	sapling
<i>Mallotus philippinensis</i>	1	20	sapling
<i>Semecarpus reticulatus</i>	1	20	sapling
<i>Ficus tinctoria</i> ssp. <i>gibbosa</i>	1	20	sapling
<i>Caryota urens</i>	1	20	sapling
<i>Flacourtia rukam</i>	1	20	sapling
<i>Clausena dunniana</i>	1	20	sapling
<i>Horsfieldia amygdalia</i>	1	20	sapling
<i>Ardisia arborescens</i>	1	20	sapling
<i>Sarcosperma kachinensis</i>	1	20	sapling
<i>Pometia tomentosa</i>	1	20	sapling
<i>Nephelium lappaceum</i> var. <i>pallens</i>	1	20	sapling
<i>Listea pierrei</i> var. <i>szemaois</i>	1	20	sapling
<i>Phoebe puwenensis</i>	1	20	sapling
<i>Glycosmis pentaphylla</i>	1	20	sapling
<i>Reevesia pubescens</i>	1	20	sapling
<i>Ficus collosa</i>	1	20	sapling
<i>Sapium baccatum</i>	1	20	sapling
<i>Ficus cyrtophylla</i>	1	20	sapling
<i>Maesa permollis</i>	1	20	shrub
<i>Litsea dilleniifolia</i>	1	20	sapling
<i>Bischoffia javanica</i>	1	20	sapling
<i>Calophyllum polyanthum</i>	1	20	sapling
<i>Randia wallichii</i>	1	20	sapling
Total: 35 species			